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Modification of a Continuous Ice Crystal Replicator

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MODIFICATION OF A CONTINUOUS ICE CRYSTAL REPLICATOR

by

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ABSTRACT

A continuous ice-crystal replicator was modified by the addition of a gear drive to the coating wheel. This modification utilizes a positive drive force on the coating wheel rather than the friction force between the coating wheel and the film. The coating wheel operates successfully for at least 12 hours without slippage or damage to the film.

Studies have uncovered several deficiencies in the replicator design which could be corrected. The correction of these deficiencies would lead to an improved quality of ice-crystal replicas.

The need for continued studies in the fluid properties of Formvar solution is pointed out. Information from such studies could be used to design more effective coating wheel configuration.

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1.0 INTRODUCTION

1.1 Objective

The objective of this design project was to modify an ice crystal replicator so that it would operate continuously for periods of time in excess of 12 hours and still produce good quality ice-crystal replicas.

1.2 Background

Project Snowman at the Utah Water Research Laboratory at Utah State University is involved in field studies to determine the effectiveness of cloud seeding as a means of snowfall augmentation. Knowledge of ice crystal growth and multiplication is an important parameter in such studies. To study the growth of ice crystals, a replicator is used to produce plastic replicas of the ice crystals. These replicas can then be examined under magnification to determine ice crystal concentrations, crystal type, temperature relationships, and the amount of rime which has accumulated.

The replicator being used by Project Snowman was built according to a model developed by Hindman and Rinker (1967) at Colorado State University, and is shown in schematic diagram in Figure 1. The complete replicator is housed in an aluminum box. When closed the only opening in the housing is that of the sampling slot through the top. Replication of ice crystals is accomplished using Schaefer's

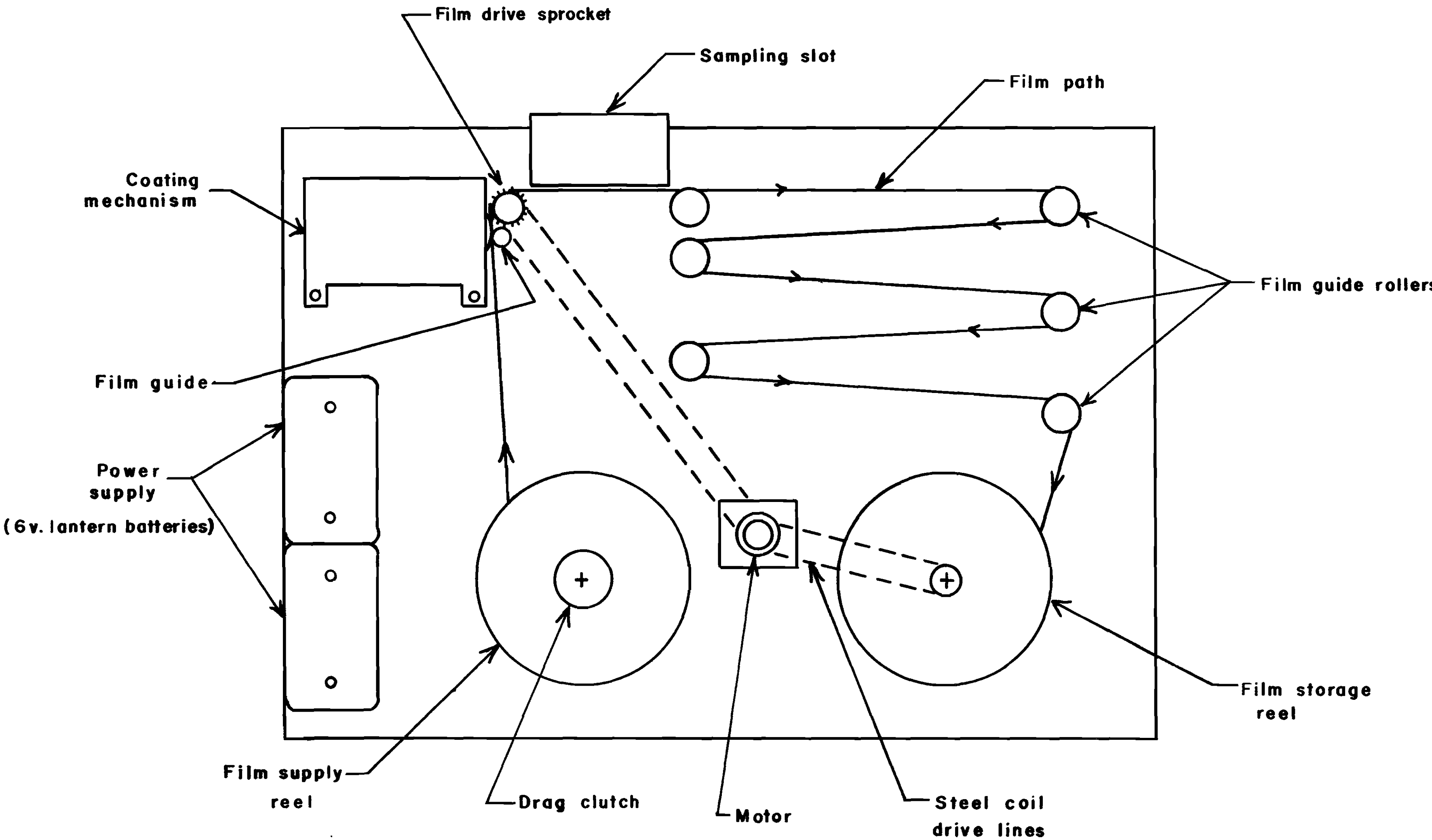

Figure 1. Schematic diagram of the Hindman-Rinker continuous ice crystal replicator.

(1956) Formvar[1] replication method. The Formvar is a synthetic resin (polyvinyl formal) which is dissolved in ethylene dichloride. One side of the 35 mm film base is coated with the Formvar solution which is drawn off the 400 ft. supply reel.[2] The coated film then passes horizontally at a speed of 7.5 cm per minute under a slot through which the ice crystals fall. Upon contact with the Formvar solution, the ice crystal becomes encapsulated by the Formvar and after a period of time the volatile ethylene dichloride evaporates. After the ice crystal sublimates, a hard white Formvar cast of the ice crystal remains on the film.

Project Snowman's model of the Hindman-Rinker replicator had several operational problems which caused the replicator to be unacceptable for field use. The most troublesome was that of coating the Formvar solution on the film. The coating was uneven and discontinuous, which caused poor quality replicas.

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[1] Trade name: Formvar 15-95, Shawinigan Products Corp., Springfield, Massachusetts.

[2] P-40B Leader, double perforated 35 mm polyester photographic film base, DuPont, Wilmington, Delaware.

2.0 MODIFICATION OF EXISTING REPLICATOR

2.1 Existing Coating Wheel

The film was coated by bringing it into contact with a coating wheel. The coating wheel assembly is shown in Figure 2. As the film passed by the face of the coating wheel, the wheel would turn, bringing Formvar solution up out of the reservoir and depositing it on the film. Investigations by MacCready and Todd (1964) along with others by Hindman and Rinker (1967) established a working design for the coating wheel. A section of the wheel is shown in Figure 3. The grooves cut horizontally in the wheel were milled to a depth of about 125 μ. The drive force which caused the wheel to rotate was solely due to the friction force between the wheel and the film. This action is illustrated in Figure 4. It was determined by observation that there was slippage at the film-wheel interface. This slippage was responsible for the uneven coating of the film. After an hour or so of operation, the wheel would stop completely due to drying of the Formvar solution on the edges of the coating wheel.

2.2 Spring Load Modification

The first modification made on the coating wheel mechanism was that of spring loading the hinged coating wheel as shown in Figure 5. By doing this, the normal force between the wheel and the film would be increased, thus increasing the friction force tangential to the wheel. With this increased tangential force on the wheel, the

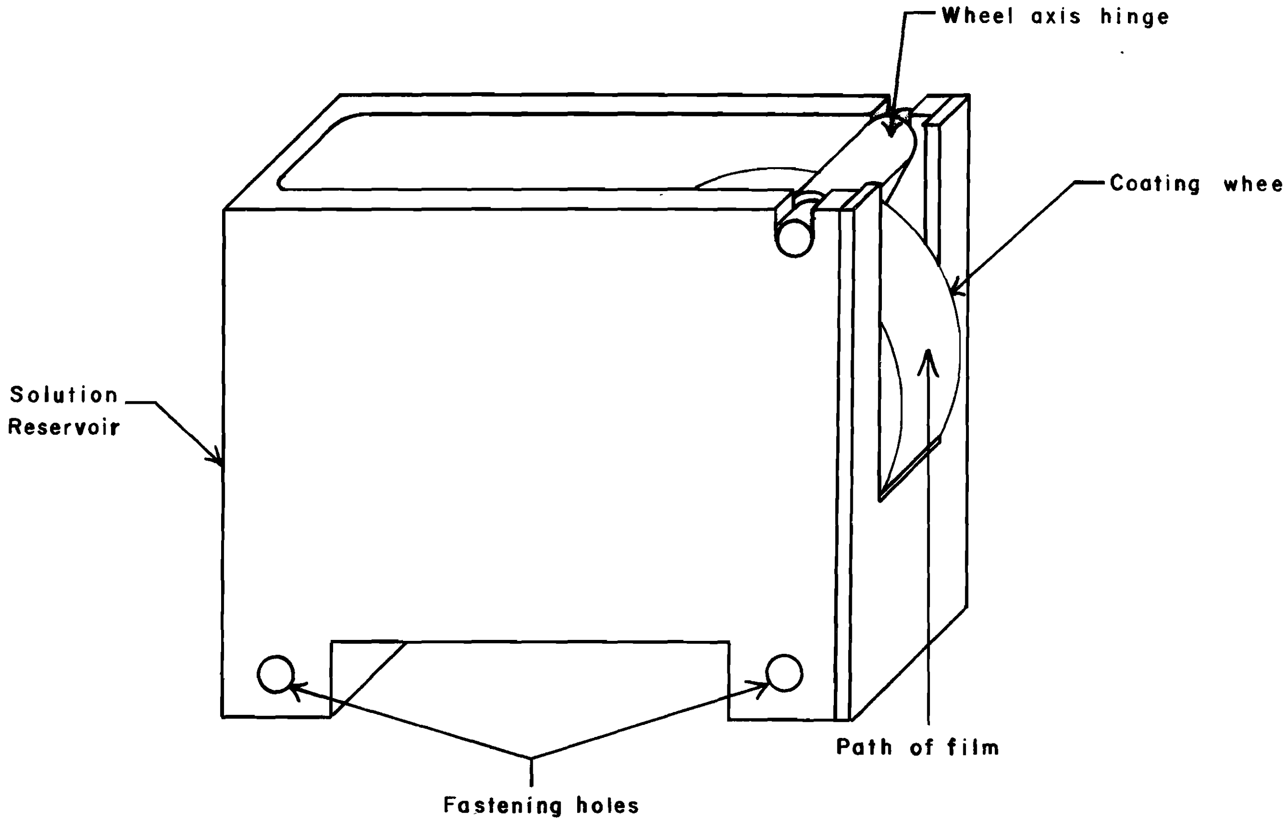

Figure 2. Coating wheel assembly (3/4 scale).

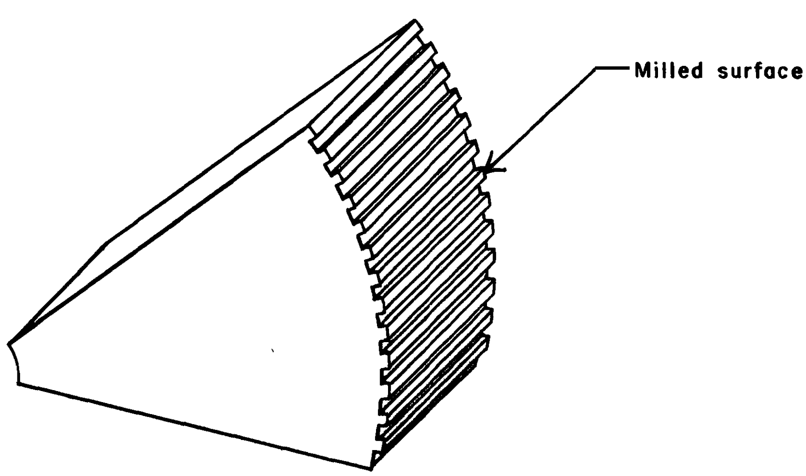

Figure 3. An enlarged section of the coating wheel.

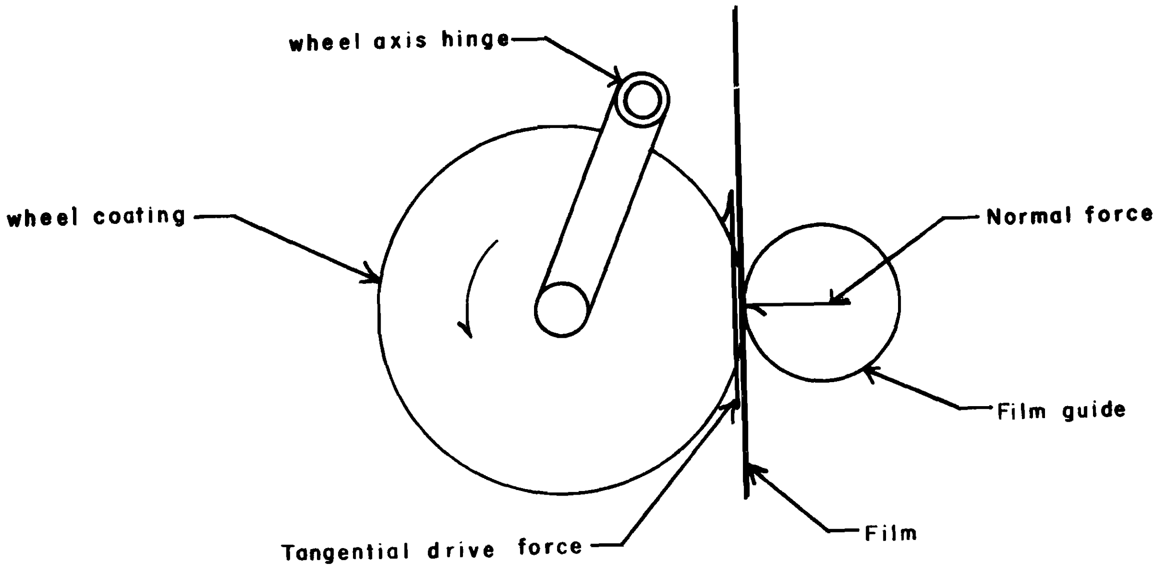

Figure 4. Diagram showing operation of and forces acting on the coating wheel before any modifications.

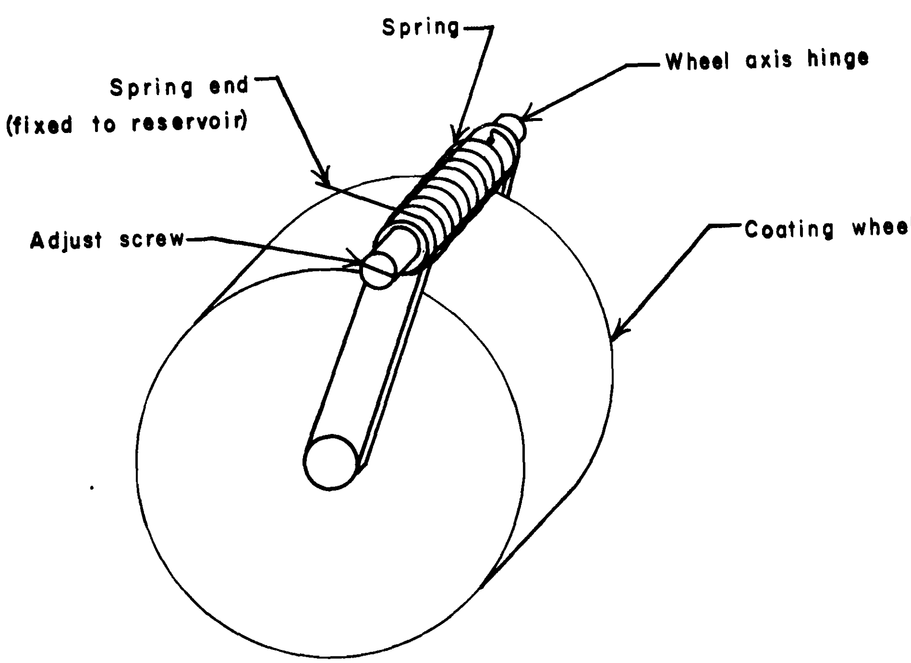

Figure 5. Sketch of the coating wheel assembly modified by the addition of a helical spring to increase the normal force.

wheel would then be dependent upon the replicator's motor rather than upon the friction force between the film and the coating wheel. Without the need for a large friction force, the normal force between the film and the coating wheel could be reduced, thereby eliminating possible damage to the film.

The coating-wheel drive was constructed by putting a spur gear on the shaft of the film-drive sprocket and letting that gear propel another spur gear placed on the coating-wheel shaft. These gears are illustrated in Figure 6.

In order to make this modification, the location of the coating-wheel shaft had to be permanently fixed. With the coating-wheel shaft in a permanent position, the wheel-axis hinge was no longer necessary, so it was removed. Therefore, two holes were drilled through opposite walls of the solution reservoir and the coating-wheel shaft was lengthened to extend through the holes. These holes then became permanent housing for the coating-wheel shaft.

For the coating wheel and the drive sprocket both to be turning with the same tangential velocities at their outside faces, it is necessary that the ratio of the pitch diameters of the gears be equal to the ratio of the coating wheel and drive sprocket diameters. The diameters of the coating wheel and the film-drive sprocket are 2.40 in. and 0.96 in., respectively. This gives a diameter ratio of:

$$\frac{D_{cw}}{D_{ds}} = \frac{2.41}{0.96} = 2.51 = \frac{2.50}{1.00} .$$

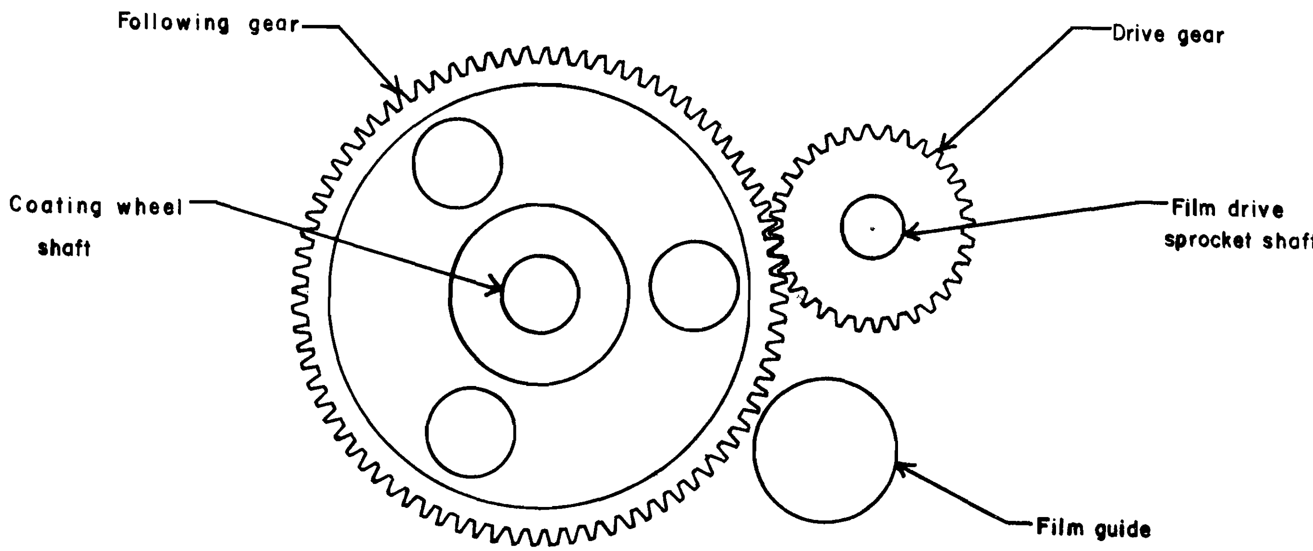

Figure 6. Spur gear configuration.

Spur gears were chosen from a catalog with pitch diameters of 2.500 in. and 1.000 in. The specifications on the gears chosen are given in Table 1.

The location of the coating wheel shaft through the walls of the solution reservoir was determined by two factors: the required distance between the two shafts on which the gears were to be placed, and the distance which the coating wheel face must protrude in order to reach the film, as illustrated on Figure 7.

Table 1. Spur gear specifications.

Boston Gear Work's Part No.	Teeth	Pitch dia.	Hole	Hub proj.	Style	List Price
Y3232[a]	32	1.000"	1/4"	1/4"	Plain	$1.80
Y3280[a]	80	2.500"	5/16"	5/16"	Web	$4.20

Another important aspect of the design is the ease with which the coating wheel can be removed for cleaning. In the new design the coating wheel and gear assembly can be easily dismantled by removing the two screws shown in Figure 8 and unscrewing (left-hand threads) the coating wheel from its shaft.

The gear drive modification solved the problem of film slippage previously encountered. Tests under actual operating conditions showed that the replicator would run for periods well in excess of 12 hours with no detectable slippage between the film and

[a]Both spur gears have a pitch of 32, a 3/16" face, and a pressure angle of 20°.

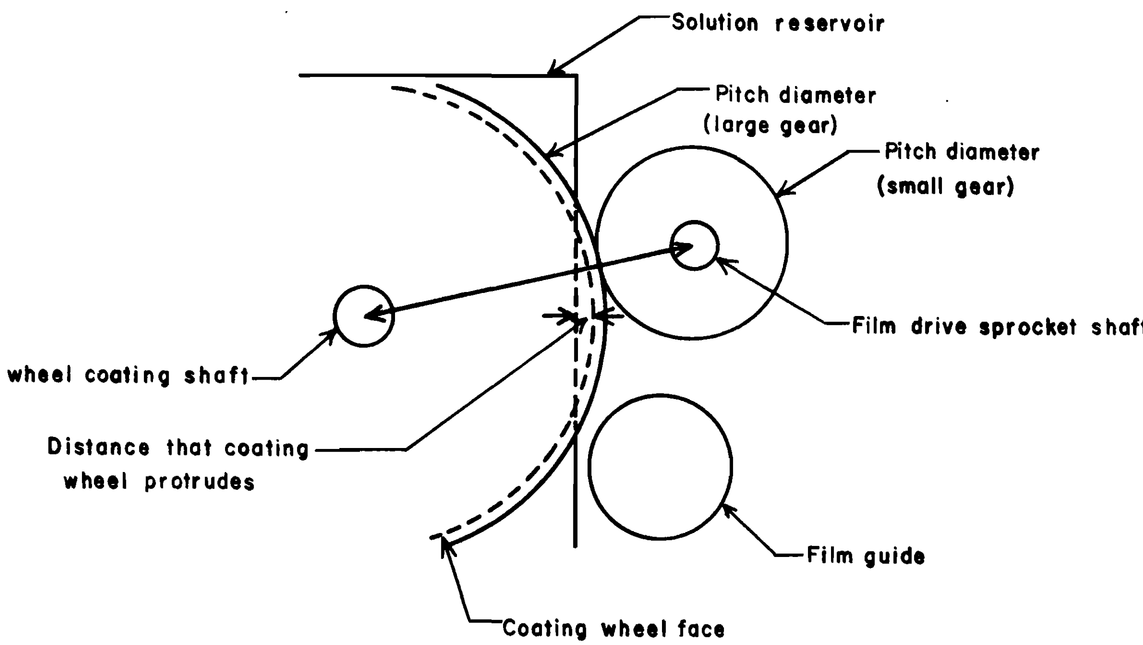

Figure 7. Sketch showing the location of the coating wheel shaft.

the coating wheel. The replicator was put into operation in early February, and excellent snowflake replicas were produced.

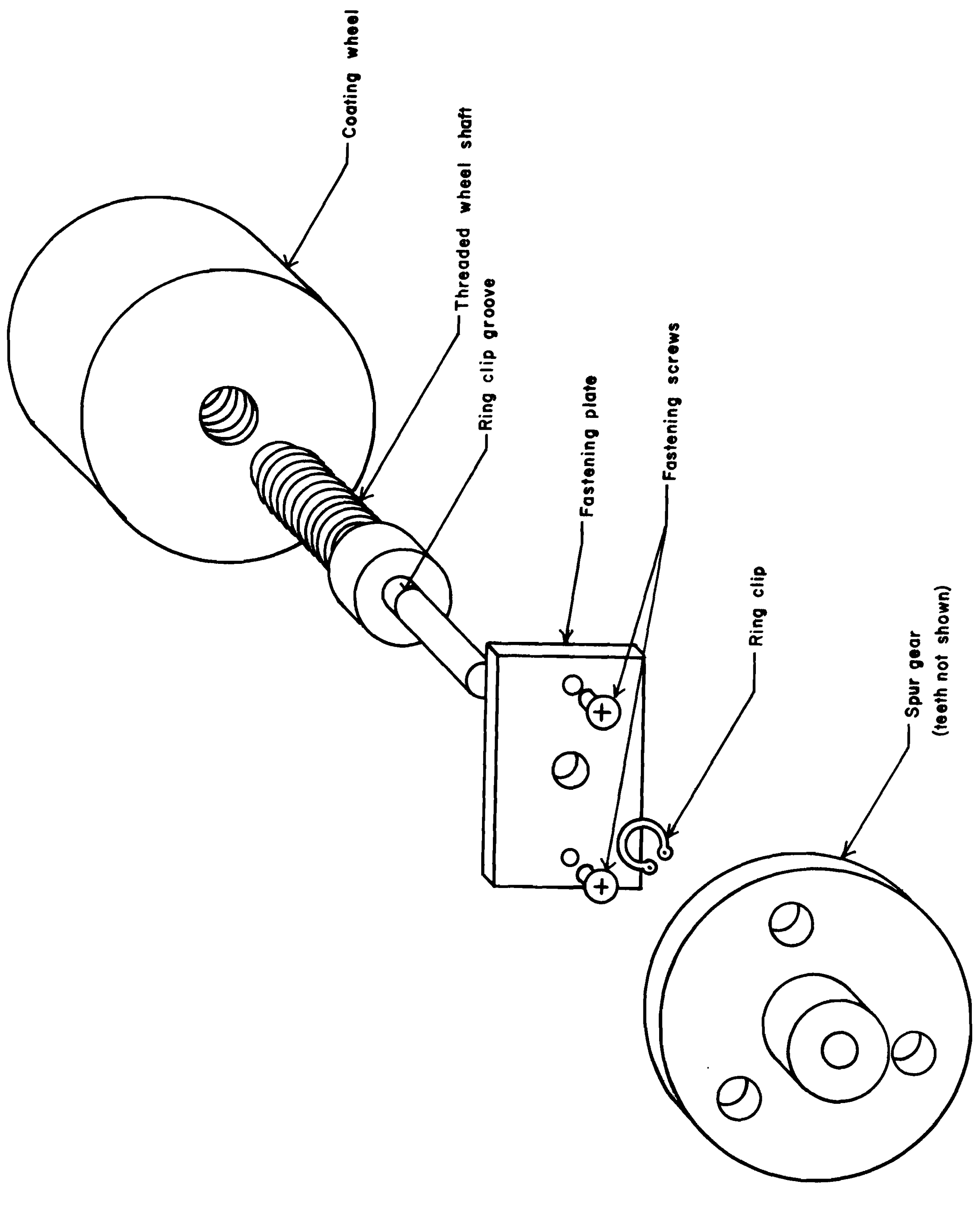

Figure 8. Components of the coating mechanism after the gear drive modification was completed. (Note: The solution reservoir is not shown.)

3.0 FUTURE DESIGN CONSIDERATIONS

Up to this point, little has been said about the operational problems associated with the replicator, aside from the coating wheel slippage. There are basically three other problems which should be studied. They are: sampling-slot configuration and location, temperature inside the replicator, and Formvar-solution viscosity changes.

3.1 Sampling-Slot Design

In the present design, an ice crystal must fall about 3 inches once it enters the sampling slot until it reaches the Formvar solution on the film. Because the ice crystals have a horizontal component of velocity, many crystals strike the sampling-slot walls and are either fractured or stick to the walls of the slot. During heavy snowfall, the accumulation of ice crystals on the sampling-slot walls has caused the slot to be completely bridged over. The sampling slot should be changed by shortening the distance from where the ice crystals enter to where they impact in the Formvar solution. Also, the walls of the slot should be made of a material with a smooth finish or coated with a very smooth surface.

3.2 Replicator Temperature

The process of replication of ice crystals by the Formvar technique works only when the complete process takes place at least

2 to 3°C below the freezing point. Due to the portable nature of the replicator, it is not practical to refrigerate the entire process, therefore, every precaution should be taken to insure that the inside of the replicator remain as cool as the ambient air temperature. In the present design, the motor and energy source are inside the replicator but vented to the outside so that they do not contribute to the replicator's internal temperature. Another factor which contributes to the replicator's temperature is solar radiation. When the replicator was first built, it was made of polished alumimum, but after exposure to the weather, the aluminum surface oxidized. The replicator therefore absorbed radiation and caused heating. An alternative design would have both replicator housing and as much of the inside as possible, made out of white plexiglas.

3.3 Formvar-Solution Viscosity

The Formvar solution used in operations consisted of 2 to 6 percent Formvar by weight dissolved in ethylene dichloride. A wide range of solution strengths was used because the viscosity varies so much with temperature. In attempt to compensate for these viscosity differences, the percentage of Formvar was increased as the temperature increased. To the writer's knowledge no research has been done to determine the relationship between solution, viscosity, temperature, and solution strength. The effectiveness of the coating wheel in applying the proper amount of Formvar solution to the film is dependent upon the viscosity of the Formvar solution. It appears that research in this area would be valuable in developing improved coating techniques.

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